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Musculoskeletal Injuries In CrossFit®: A Systematic Review and Meta-Analysis of Injury Rates and Locations

Verletzungen des Bewegungsapparates im CrossFit®: systematisches Review und Metaanalyse zu Verletzungsraten und -lokalisation

REVIEW

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Summary

- **Background:** CrossFit® is a popular high-intensity, functional strength sport. Reviews of CrossFit® epidemiology lack a clear definition of 'injury'.
- **Objectives:** Based on a three-step definition of 'injury' with time-loss and medical attention, the existing literature was to be reviewed to determine injury rates in CrossFit® and the most affected body regions.
- **Methods:** Following the PRISMA-statement, four literature databases were searched for studies related to epidemiology in CrossFit®. Studies found were reviewed for evidence and quality of reporting through the OCEBM Levels of Evidence and the STROBE statement.
- **Results:** Thirty-two studies were included in the qualitative review and fourteen studies were included in the meta-analysis. The included studies were of level 3 and 4 of evidence and reported 14-22 items of the STROBE-checklist. A prevalence of 30.3% (95% CI: 25.3-35.3%) and an incidence of 3.20/1.000 hours (95% CI: 2.06-4.34) were calculated for musculoskeletal injuries in CrossFit®. Spine (26.8%, 95% CI: 20.6-33.0%), shoulder (25.9%, 95% CI: 20.1-31.6%), and knee (15.8%, 95% CI: 11.8-19.7%) were most affected.
- **Conclusion:** Musculoskeletal injury rates and affected body regions in CrossFit® are comparable to weightlifting and powerlifting. These findings suggest that recommendations for injury prevention in CrossFit® might not differ from generalized recommendations in strength sports. Studies of higher quality are needed to improve epidemiology data.

Zusammenfassung

- **Hintergrund:** CrossFit® ist eine beliebte hochintensive, funktionelle Kraftsportart. Reviews zur CrossFit®-Epidemiologie lassen eine klare Definition von „Verletzung" vermissen.
- **Zielstellung:** Basierend auf einer dreistufigen Definition von „Verletzung" mit Zeitverlust und medizinischer Versorgung sollte die vorhandene Literatur gesichtet werden, um Verletzungsraten im CrossFit® und die am meisten betroffenen Körperregionen zu ermitteln.
- **Methodik:** Auf Grundlage des PRISMA-Statements wurden vier Literatur-Datenbanken auf Studien zur Epidemiologie im CrossFit® durchsucht. Gefundene Untersuchungen wurden durch die OCEBM Levels of Evidence und das STROBE-Statement auf Evidenzniveau und die Qualität der Berichterstattung überprüft.
- **Ergebnisse:** 32 Studien wurden in die qualitative Untersuchung und vierzehn Studien in die Metaanalyse einbezogen. Die inkludierten Untersuchungen waren vom Evidenz-Level 3 und 4 und berichteten 14-22 Items der STROBE-Checkliste. Eine Prävalenz von 30,3% (95% CI: 25,3-35,3%) sowie eine Inzidenz von 3,20/1.000 Stunden (95% CI: 2,06-4,34) für Verletzungen am Bewegungsapparat im CrossFit® wurden berechnet. Wirbelsäule (26,8%, 95% CI: 20,6-33,0%), Schulter (25,9%, 95% CI: 20,1-31,6%) und Knie (15,8%, 95% CI: 11,8-19,7%) waren am häufigsten betroffen.
- **Schlussfolgerung:** Verletzungsraten und betroffene Körperregionen im CrossFit® ähneln denen des Gewichthebens und Powerliftings. Diese Erkenntnisse legen nahe, dass die Empfehlungen zur Verletzungsprävention beim CrossFit® den allgemeinen Empfehlungen im Kraftsport gleichen könnten. Studien höherer Qualität werden für ein besseres Verständnis der Epidemiologie benötigt.

KEY WORDS:
Prevalence, Incidence, Strength Training, High Intensity Functional Training

SCHLÜSSELWÖRTER:
Prävalenz, Inzidenz, Krafttraining, Hochintensives funktionelles Training

Introduction and Objectives

CrossFit® represents one of the biggest fitness trends in recent times (11). In 2021, more than five million athletes engaged in CrossFit® activities in over 14,000 locations worldwide (9). CrossFit® workouts consist of specific combinations of elements derived from metabolic conditioning (running, rope skipping, etc.), gymnastics (push-ups, sit-ups, etc.), and weightlifting/throwing (deadlifts, squats, etc.) (8, 27, 28). A combination of exercises from the elements is often applied: 1) time restricted, 2) interval-based at a high intensity or 3) with focus on exhaustion, often allowing limited time to recover between sets (5, 8, 54). This is similar to other forms of High Intensity Functional Training (HIFT) and Extreme Conditioning Programs (ECP) (4, 22). Many CrossFit® athletes take part in competitions (19.3%-74.5%) (41, 47), ›

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e.g. 'The Open' (20). Affiliate programs and offering standardized 'Workouts Of the Day' differentiates CrossFit® from other types of HIFT and ECP. Due to this unique training regime, potential benefits and risks of CrossFit® need to be investigated exclusively without mixing with other types of HIFT and ECP.

Carrying out high-intensity exercises in fatigued states is associated with an increased injury risk which has been demonstrated in ECP (4, 5). Aune & Powers (2017) have determined the prevalence and incidence of musculoskeletal injuries in ECP. Injury rates similar to weightlifting were found, and the shoulder was identified as the most commonly injured body region (4). In 2018, Claudino et al. published a meta-analysis on different dimensions of CrossFit® such as body composition and psychophysiological parameters. Injury risk was also assessed, reporting injury prevalences between 19%-74% and incidence rates of 1.9-3.1 per 1,000 training hours (7). Injury data, however, was not included in the meta-analytical part of the study, limiting a more detailed and quantified analysis. Gean et al. (2020) reported CrossFit® injuries to the back, shoulder and knee to be comparable to other forms of weightlifting programs in frequency and occurrence (25). Rodríguez et al. (2021) proposed a similar conclusion regarding injury risk in CrossFit®, but again without providing pooled data on prevalence and incidence rates (52). Furthermore, and similar to other original studies (2, 14, 59), a clear definition of an injury as an inclusion criterion was not provided in those manuscripts. Eliminating this potential essential bias (52) by formulating a precise definition of an injury might facilitate the determination of a more comparable and reliable epidemiology profile.

Objectives of this study are therefore 1) to analyze musculoskeletal injury rates in CrossFit® based on a precise definition of 'injury' through a systematic review and a meta-analysis to determine prevalence and incidence rates, and 2) to identify the body regions most affected by CrossFit®-related injuries based on this definition.

Methods

The research was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (48). Steps of literature search and selection, data extraction as well as quality assessment were performed by two reviewers independently (MH and KR) with a third reviewer for consensus (TB).

Definitions

A definition of 'injury' was created considering the criteria of 'time loss', 'training modification' and 'medical attention' based on injury surveillance studies in sports (6, 51) as used in other meta-analyses (42, 61) and on the 'three days on and one day off' principle of CrossFit® (8, 27):

1. Total withdrawal from CrossFit®-training or competition for at least three days; OR
2. Modification of training conditions (e.g. in scope, intensity, etc.) for at least three days; OR
3. Severe enough to seek medical attention.

Prevalence represents the period prevalence and relates to all injuries that occurred during exposure to CrossFit® within the original study duration in relation to the total population. Incidence was defined as the amount of newly sustained injuries per 1,000 hours of exposure to CrossFit®.

Eligibility Criteria

Participants had to work out in an affiliated CrossFit® facility. Studies were included, if at least one of the above criteria of 'injury' was met. There were no limitations to participant's age, sex or health nor to study age, length or design. Meta-analyses and reviews were excluded but used for citation tracking. Conference abstracts, letters or comments were excluded. Language was limited to English and German.

Literature Search

Electronical databases were searched from inception until 18th of February 2021: PubMed, Cochrane Library, ScienceDirect and Web of Science. The search terms "Injur*", "CrossFit", "High Intensity Functional Training", "Extreme Conditioning Program" were used with Boolean operators. For example, for PubMed the string "All Fields: Injur* AND (CrossFit OR "High Intensity Functional Training" OR "Extreme Conditioning Program")" was used with limitations "Language: English, German".

Data Collection

If available, the following data have been extracted and analyzed in Microsoft Excel 2010 Version 14.0: authors with year of publication, study size, origin and design as well as study duration, eligibility criteria of participants and time period during which injuries were sustained. For CrossFit®-related epidemiology the number of injured participants (and amount of injuries), prevalence and incidence rates, injured body region, diagnosis and other findings were recorded.

Evaluation Tools

The Oxford Centre for Evidence-Based Medicine (OCEBM) 2011 Levels of Evidence (50) were used and the fourth column was supplemented by 'case-control studies' and 'case reports'.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (15) was used for assessing the quality of reporting and risk of bias in cohort and cross-sectional studies.

Certainty of evidence was evaluated with the Cochrane Handbook for Systematic Reviews of Interventions, utilizing the GRADE approach from 'very low', 'low', 'moderate' and 'high certainty of evidence' for each outcome (30).

Data Handling and Analysis

Data were extracted from tables, graphs or calculated from available data and were presented as median, minimum and maximum.

The meta-analysis was conducted using the random effects model and presented with a confidence interval (CI) of 95% (49) for prevalence and incidence of musculoskeletal injuries based on cohort and cross-sectional studies. Studies reporting multiple injured body regions were used to determine the three most affected regions by CrossFit®-related injuries.

Heterogeneity was evaluated by examining Cochran's Q, I^2 (49) and funnel plots. I^2 thresholds for heterogeneity were 0-40%, 30-60%, 50-90% and 75-100% for 'might not be important', 'moderate', 'substantial' and 'considerable heterogeneity' (30).

Results

Study Selection

The literature search and citation tracking led to 278 hits. After removing duplicates 208 records were screened based on title and abstract. 99 full-text articles were assessed for eligibility. The remaining 32 articles were included in the systematic review. Studies presenting prevalence, incidence rates or reporting multiple injured body regions were included in the meta-analysis. The detailed selection process is presented in figure 1. The pertinent part of the definition of 'injury' in eligible cohort and cross-sectional studies is presented in table 1 (see supplemental material online).

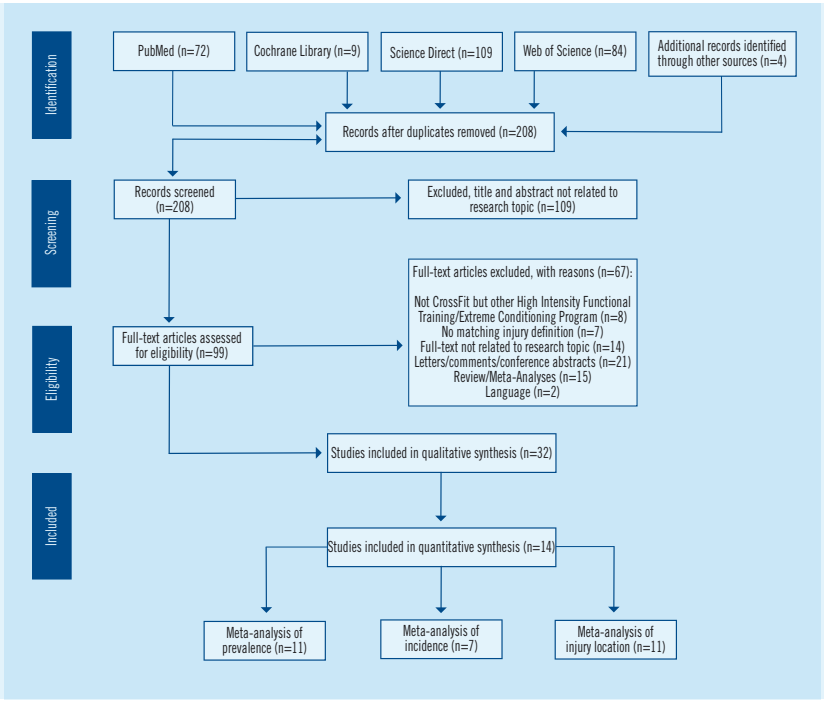

Figure 1

Selection process flow chart.

Study Characteristics

Eleven studies were case reports (13, 17, 23, 24, 29, 31, 36, 45, 46, 53, 58), ten were cross-sectional studies (10, 16, 20, 21, 41, 44, 47, 54, 57, 60), six were case series (3, 19, 33–35, 43), four were retrospective cross-sectional studies (18, 32, 55, 56) and one study was of prospective cohort design (39). The duration of the prospective study was eight weeks (39). Injuries were assessed prospectively for 'eight weeks' (39) and retrospectively for 'past six months' (47, 57, 60), 'past twelve months' (16, 20, 21, 41, 44, 47) and 'ever' (10, 47, 54). Two studies reported different results from the same data (55, 56); only one dataset was used for our analysis (55). The detailed characteristics and findings of the eligible studies are presented in tables 2 and 3 (see supplemental material online). The included studies were of evidence level three and four. The STROBE-statement checklist ranged from 14 to 22 reported items (median: 20) (Table 2, see supplemental material online). Items not being reported were, e.g. explanation of handling of quantitative variables, information about participants and participation, and information on funding. Certainty of evidence was low for prevalence and body regions because of observational study design. Certainty of evidence was very low for incidence due to observational study design and inconsistency.

Study Sample

The qualitative analysis included 9,306 participants. Three studies provided limited or no data on sex (n=601) (32, 57, 60); 4,622 were male (53.1%) and 4,083 were female (46.9%). Sample sizes ranged from 1 in the case reports to 3,049 in one cross-sectional study.

Injury

Prevalence Rates

Eleven studies reported prevalence rates (10, 16, 20, 21, 39, 41, 44, 47, 54, 57, 60). In this sample, 2,395 of 7,612 participants reported having sustained at least one injury. The prevalence in the studies ranged from 14.9% (39) to 56.1% (44). The pooled prevalence of musculoskeletal injuries in CrossFit® was 30.3% with moderate heterogeneity (95% CI: 25.3-35.3%, df=10, Q=19.65, I^2=49.1%) (Figure 2). Studies reported 14-22 items of the STROBE-checklist (median: 20) (Table 2) (see supplemental material online).

Incidence Rates

Five studies presented average incidence rates (10, 16, 39, 41, 47), one study published the incidence rate retrospectively (26), and one study reported incidence rate on shoulder injuries only (57). In a sample of 1,997 participants 626 injuries were sustained. Observation periods differed considerably among studies and included six months (47, 57, 60), twelve months (16, 41, 47), ever (10, 47) or were prospectively assessed over eight weeks (39). Incidence rates ranged from 0.8/1,000 hours (41) to 9.5/1,000 hours (39). The pooled incidence of musculoskeletal injuries in CrossFit® was 3.20/1,000 hours with substantial heterogeneity (95% CI: 2.06-4.34, df=6, Q=21.31, I^2=71.8%) (Figure 2). Studies reported 14-22 items of the STROBE-checklist (median: 18) (Table 2) (see supplemental material online).

Body Regions

Eleven studies presented multiple body regions affected by CrossFit®-related musculoskeletal injuries (10, 16, 18, 21, 32, 39, 41, 44, 47, 55, 60). Overall, 6,769 participants have been included in these studies, 3,245 of whom provided information about the injured body region. The most affected anatomical regions were: spine with 26.8% (95% CI: 20.6-33.0%, df=10, Q=6.38, I^2=0%), shoulder with 25.9% (95% CI: 20.1-31.6%, df=10, Q=9.43, I^2=0%), and knee with 15.8% (95% CI: 11.8-19.7%, df=10, Q=8.01, I^2=0%). Heterogeneity for each body region might not be important. Studies reported 14-22 items of the STROBE-checklist (median: 20.5) (Table 2) (see supplemental material online).

Case series and reports presented 118 injured CrossFit® participants and demonstrated specific injuries to head (3, 36), neck (24), trunk (23, 31), upper extremities (13, 29, 58), hip/groin (19), knee (35, 53) and multiple regions (17, 33, 34, 43, 45, 46). The injured body regions with respective diagnosis are listed in table 3 (see supplemental material online).

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Discussion

Based on a clear injury definition, the purpose of this study was to analyze musculoskeletal injury rates in CrossFit®. The results showed an average prevalence of 30.3% and an average incidence rate of 3.20/1,000 hours. The second objective was to determine the body regions most affected by CrossFit®-related musculoskeletal injuries. Analysis revealed spine (26.8%), shoulder (25.9%) and knee (15.8%) being affected most.

Moderate heterogeneity for prevalence (I^2=49.1%) and substantial heterogeneity for incidence (I^2=71.8%) in this analysis could be the result of including studies with high risk of bias (12). In terms of sensitivity, analysis on study origin with a leave-one-out validation did not explain existing statistical heterogeneity. Analyses of funnel plots seem to verify a small study effect, where smaller studies produce larger effects (12).

Prevalence and Incidence Rate

Our prevalence of 30.3% is similar to 35.3% reported by Rodríguez et al. (2021) (52). The meta-analytic approach seems to be more precise and the true injury prevalence in CrossFit® might be lower than previously assumed.

In our study, the range of reported incidence rates varied from 0.8/1,000 hours (41) to 9.5/1,000 hours (39). Differences might be due to study designs or study durations. Also, these discrepancies could be explained by varying CrossFit®-experience; the study with lower rate excluded participants with less than six months experience and the study with higher rate followed CrossFit®-beginners.

Musculoskeletal injury incidence rates in CrossFit® do not seem to largely differ from those of other forms of strength sports. Aasa et al. (2017) described injury rates in weightlifting of 2.4-3.3/1000 hours and 1.0-4.4/1000 hours in powerlifting (1). Keogh & Winwood (2017) demonstrated injury rates of 0.24-1.0/1,000 hours in bodybuilding, 2.4-3.3/1,000 hours in weightlifting, 1.0-5.8/1,000 hours in powerlifting, 4.5-6.1/1,000 hours in 'strongman', 7.5/1,000 hours in Highland Games and 3.1/1,000 hours in CrossFit® (37). In the review by Keogh & Winwood (2017) only one study was available for each Highland Games and CrossFit® and so these data are not sufficient to adequately represent overall incidence. Those reviews did not impose any limitation on the definition of an injury but came to a comparable incidence rate to our study. Our musculoskeletal incidence rate in CrossFit® (3.20/1,000 hours) reveals that the rate of injury is lower compared to 'strongman' and Highland Games but higher than the rates in bodybuilding, and equal to those in weightlifting and powerlifting. Strongman and the traditional Highland Games (a modern form of ancient competitions) have high demands on body and muscle strength and, like CrossFit®, are characterized by a competitive nature. One study found that CrossFit®-competitors did not have higher injury rates than non-competitive participants (20). Potential risk factors (e.g. competition participation), and more detailed reporting of epidemiology (e.g. mode of onset and severity of injuries), should be addressed by future research.

Our findings in injury rates and affected body regions are similar to other reviews in strength sports that did not use a strict definition of injury. Though one might conclude that a strict definition could be omittable to assess injury epidemiology in this case, comparability and quality assessments of future research might still benefit from a uniform utilization of the term 'injury'.

Body Regions

In CrossFit® similar body regions are affected by musculoskeletal injuries like in other strength sports. In our analysis, CrossFit® mainly affected the spine, shoulder and knee. In the review of injuries in strength sports by Keogh & Winwood (2017), the five most common injury sites were the shoulder, lower back, knee, elbow, and wrist/hand (37). Similarities are probably due to the fact that CrossFit® includes elements from weightlifting and powerlifting.

Functional movements and their capacity to move large loads over long distances quickly is an important part of CrossFit® (8, 28). This can lead to early fatigue during workout and impairments in motor execution with the result of risk of injury. Regular heavy loads can lead to overuse injury patterns such as tendinopathies, e.g. in the knee (patellar tendon) due to deep knee flexion in squats or snatches (40). Injuries to the spine might be caused by heavy loads with an axial loading, e.g. in squats and deadlifts. Both exercises require the spine to remain in a specific position and early workout fatigue might impair the correct posture. The combination of high load and fatigue can even lead to increased intradiscal pressure and disk herniation (32). In strength sports, the shoulder often is in a position of extreme flexion and abduction (40) and is required to carry weight in a non-weight bearing joint (38), which may account for some injuries to this body part. Furthermore, high-intensity combined with ballistic movements and heavy weights in some exercises in CrossFit® (e.g. snatch, muscle-up, etc.) might explain ballistic-type injuries to multiple joints.

Based on injury rates and injured body regions in our study that are similar to those of other forms of strength sports, recommendations for injury prevention in CrossFit® might not differ considerably from generalized recommendations. Greater caution, more awareness and attention from trainers and participants, additionally carefully scaling loads when performing CrossFit® workouts, might help to reduce injuries during workouts. Contradictory risk factors mentioned in the included literature, such as sex, CrossFit® experience and previous injuries might have influenced injuries to specific body regions and additional research is necessary to determine the cause of injuries in CrossFit® further. Although regular medical checks (especially of the musculoskeletal system) are undisputedly beneficial, no specific conclusions or recommendations with respect to their efficacy can be drawn at this time.

Strengths and Limitations

In contrast to other reviews and meta-analyses focusing on musculoskeletal injuries in CrossFit®, this is the first study to use an a priori formulated definition of an injury. A uniform definition can create comparability between studies for researchers, but also allows for simplification for participating subjects. The strict focus to affiliated gyms and their participants allows an evaluation of musculoskeletal injuries that is more specifically applicable to CrossFit®. Case series and case reports reveal specific patterns and diagnoses of injuries and may, therefore, be of value for practical application in medical settings as cross-sectional studies rarely presented these information.

However, there are some limitations that need to be addressed. Investigations which also worked with a specific injury definition and/or focused on affiliated CrossFit® gyms but did not mention it could have been missed due to our inclusion criteria. The focus on CrossFit® instead of other HIFT/ECP training has

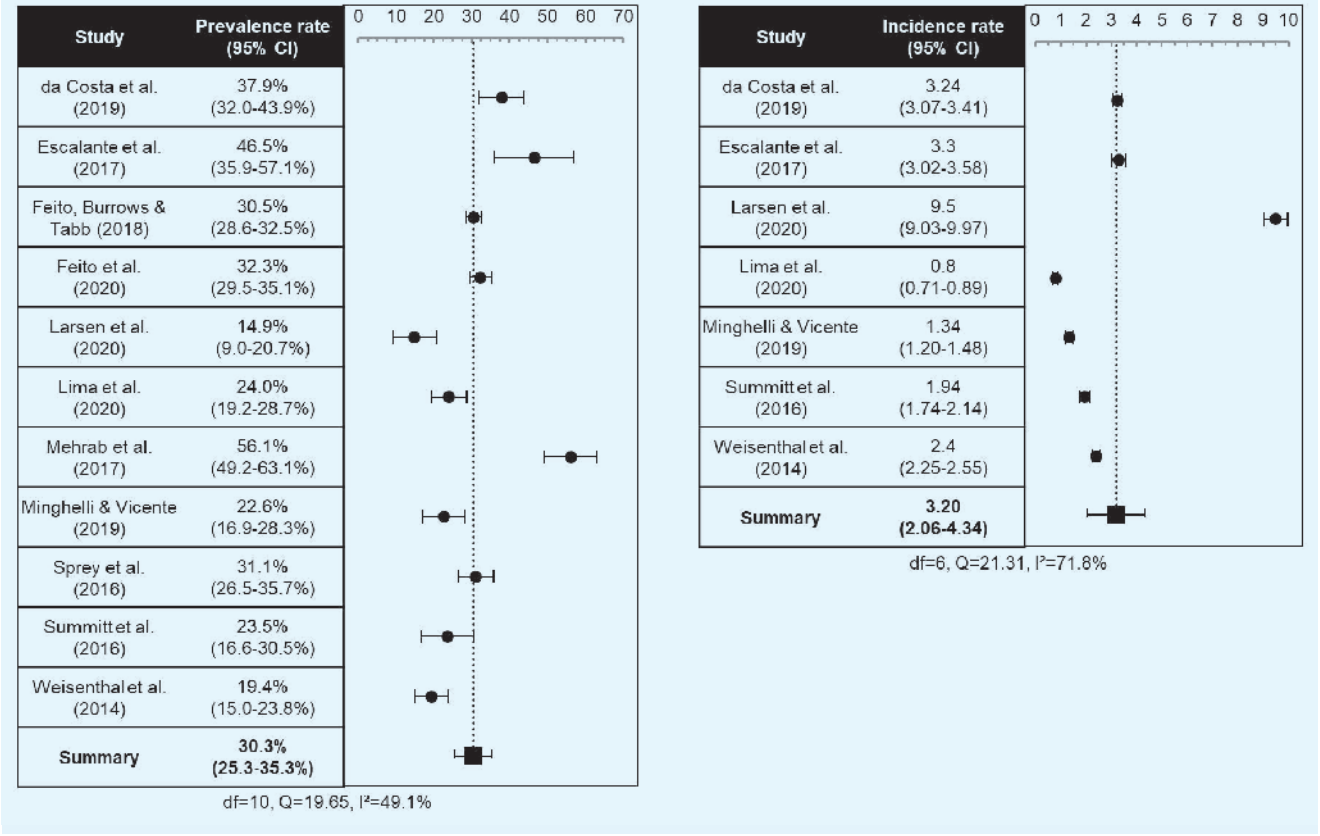

Figure 2

Prevalence and incidence of musculoskeletal injuries in CrossFit®.

proven to be difficult at times as one included study reported some participants not working out in affiliated gyms (20). Nonetheless, we included this study as only a small number of participants (7.0%) were working out in non-affiliated gyms. Despite the potential for bias to our findings, leaving this study out was not associated with substantially different results.

Potential biases in the original studies, i.e. regarding participant selection as well as publication bias and bias in the reporting of results cannot be ruled out. The two studies with the biggest sample sizes were excluded from meta-analysis of incidence as they reported incidence of injury in ranges, which is a different parameter compared to other studies and might have biased the result (20, 21).

Conclusion

Musculoskeletal injury rates and affected body regions in CrossFit® are comparable to those of weightlifting and powerlifting. In addition, our findings are similar to other reviews that did not use a strict definition of injury. Overall, studies of higher levels of evidence and a lower risk of bias are required, and more prospective cohort studies should be used for future research to improve epidemiology data in order to prioritize injury prevention.

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Conflict of Interest

The authors have no conflict of interest.

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